Carbonation

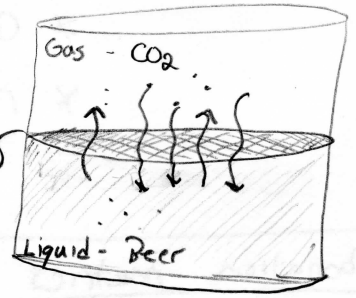
The fermentation step transforms wort into green beer. The final step is to carbonate and condition to create consumable beer.

There are three methods for Carbonation

1) Forced carbonation
2) Natural carbonation
3) Priming or Bottle conditioning

Henry's Law

$y_i P = x_i H_i$



Forced carbonation

Forcing CO_2 into solution by increasing the head space pressure. To quicken the solvation time CO_2 is fed into a diffusion stone that sits in the beer. This sintered carbonation stone is highly porous and forms many CO_2 bubbles that increase the interface area between the gas and liquid phases.

* Easy
* Relatively cheap
* Against Reinheitsgbot

Natural Carbonation

The fermentation vessel is sealed prior to completion of fermentation, allowing the head space to increase in pressure and auto-carbonate the beer.

* Natural product
* Free

* Not all volatiles may be removed from beer.

Priming

Green beer is bottled / casked and additional fermentable material is added. Beer must contain yeast, hence must not be filtered.

* Conditioning allows for more flavor development
* more time required to carbonate.

Carbonation metrics

Amount of carbon dioxide is measured in volumes

1 volume = 1 Liter of CO_2 dissolved in 1 Liter of beer

Ideal Gas behavior

@ S.T.P. $\frac{1 \text{ mole}}{22.4 \text{ liters}} \cdot \frac{1 \text{ Liter } CO_2}{1 \text{ Liter beer}} \cdot \frac{44 \text{ g } CO_2}{\text{mole}} = \boxed{1.96 \text{ grams } CO_2}$

$$[100 \text{ grams maltose}] + [0.5 \text{ grams Amino Acids}] \rightarrow [48.6 \text{ grams Ethanol}] + [46.6 \text{ grams } CO_2] + [\sim 4.9 \text{ grams yeast growth}]$$

100 grams maltose $\rightarrow$ 46.6 grams CO_2

$\frac{46.6}{100} = \sim 47\%$

example

If you wanted to have 2.5 volumes of CO_2 using natural carbonation with following Recipe, when should you seal the fermentation vessel?

O.G. — 14° P

F.G. — 4° P

2.5 volumes : $\frac{2.5 \text{ Liters } CO_2}{\text{Liter Beer}} \cdot \frac{1 \text{ mole } CO_2}{22.4 \text{ Lit. } CO_2} \cdot \frac{44 \text{ g } CO_2}{\text{mole } CO_2} = \frac{4.91 \text{ grams } CO_2}{\text{Liter beer}}$

$\frac{4.91 \text{ grams } CO_2}{47\%} = 10.44 \text{ grams extract (malt)}$

$\frac{10.44 \text{ grams extract}}{1000 \text{ grams wort}} \cdot 100 = 1.044 \text{ °P}$

$1.044\text{°P} + 4\text{° P} = \boxed{5.044 \text{ °P}}$

Typical Volumes for Some beer Styles

English Pale Ale	1.48 - 2.25
Brown Ale	1.48 - 2.47
English Bitter	0.74 - 1.28
Dry Stout	1.58 - 2.98